CLAIMS

We claim:

1. A fiducial marker holder apparatus (20) for image-guided surgery comprising:

an open-ended frame (30) having first and second arms (32, 33), the open-ended frame (30) being configured to be removably attached to a maxillary holding device (50) and the first arm (32) having at least one marker attachment point (48a-48h) that receives fiducial markers (48); and

a marker attachment device (40) disposed at a distal end of the second arm (33) of the open-ended frame (30), the marker attachment device (40) having a plurality of marker attachment points (48a-48h) that receive fiducial markers (48), at least two of the marker attachment points (48a-48h) of the marker attachment device (40) being configured to receive fiducial markers (48) in different orientations with respect to the marker attachment device (40) and each other (48a-48h).

2. The fiducial marker holder apparatus (20) according to claim 1, wherein the marker attachment device (40) is movably attached to the second arm (33) of the open-ended frame (30).

3. The fiducial marker holder apparatus (20) according to claim 2, wherein the marker attachment device (40) is configured to be fixedly oriented in more than one position.

4. The fiducial marker holder apparatus (20) according to claim 1, further comprising an additional marker attachment device (40) disposed at a distal end of the first arm (32) of the open-ended frame (30), the additional marker attachment device (40) having a plurality of marker attachment points (48a-48h) that receive fiducial markers (48).

5. The fiducial marker holder apparatus (20) according to claim 1, wherein the marker attachment points (48a-48h) are each configured as one of a threaded socket, a threaded post, a through-hole, a post, a socket and a detent.

6. A fiducial marker holder apparatus (120, 220) for image-guided surgery comprising:

a maxillary holding device (50) configured to be temporarily secured to only a maxillary-region of a patient;

an open-ended frame (130, 230) having first and second arms (132, 232, 133, 233), the open-ended frame (130, 230) being configured to be removably attached to the maxillary holding device (50), the first arm (132, 232) having at least one marker attachment point (148a-148n, 248a-248l) that receives fiducial markers (48) and the second arm (133, 233) having a plurality of marker attachment points (148a-148n, 248a-248l) that receive fiducial markers (48), at least two of the marker attachment points (148a-148n, 248a-248l) of the second arm (133, 233) being configured to receive fiducial markers (48) in different orientations with respect to the open-ended frame (130, 230) and each other (148a-148n, 248a-248l).

7. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the open-ended frame (130, 230) is rigid.

8. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the open-ended frame (130, 230) is formed of one of a carbon-fiber material, a non-metallic composite, and a polymeric material.

9. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the marker attachment points (148a-148n, 248a-248l) are each configured as one of a threaded socket, a threaded post, a through-hole, a post, a socket and a detent.

10. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the second arm (133, 233) has a first portion (133a, 233a) and a second portion (133b, 233b) extending at an angle (α) from the first portion (133a, 233a).

11. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the first arm (132, 232) has a plurality of marker attachment points (148a-148n, 248a-248l) that receive fiducial markers (48) and the first arm (132, 232) has a first portion (132a, 232a) and a second portion (132b, 232b) extending at an angle (α) from the first portion (132a, 232a).

12. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the maxillary holding device (50) includes a locking dental acrylic resin splint that is custom molded for a particular patient.

13. The fiducial marker holder apparatus (120, 220) according to claim 6, wherein the maxillary holding device (50) is fastened directly to the patient by fasteners.

14. A fiducial marker holder system (120, 220) for image-guided surgery comprising:

a maxillary holding device (50) having a first clamping part (52), a second clamping part (54) and a fixing tool (56), the fixing tool (56) being configured to temporarily secure the first and second clamping parts (52, 54) to only a maxillary-region of a patient;

an open-ended frame (130, 230) having first and second arms (132, 232, 133, 233), the open-ended frame (130, 230) being configured to be removably attached to the maxillary holding device (50), the first arm (133, 233) having at least one marker attachment point (148a-148n, 248a-248l) that receives fiducial markers (48) and the second arm (133, 233) having a plurality of marker attachment points (148a-148n, 248a-248l) that receive fiducial markers (48), at least two of the marker attachment points (148a-148n, 248a-248l) of the second arm (133, 233) being configured to receive fiducial markers (48) in different orientations with respect to the open-ended frame (130, 230) and each other (148a-148n, 248a-248l); and

a reference emitter (90) configured to be removably attached to the maxillary holding device (50) or the open-ended frame (130, 230).

15. The fiducial marker holder system (120, 220) according to claim 14, wherein the open-ended frame (130, 230) is formed of a rigid material.

16. The fiducial marker holder system (120, 220) according to claim 14, wherein the first arm (132, 232) has a plurality of marker attachment points (148a-148n, 248a-248l) that receive fiducial markers (48).

17. The fiducial marker holder apparatus (120, 220) according to claim 14, wherein the marker attachment points (148a-148n, 248a-248l) are each configured as one of a threaded socket, a threaded post, a through-hole, a post, a socket and a detent.

18. A method of performing image-guided surgery on a patient using a maxillary holding device (50), an open-ended frame (30, 130, 230), a plurality of fiducial markers (48), a reference emitter (90), a surgical probe/instrument (320) and an image-guided surgical system (300) having a tracking sensor (325), the method comprising:

(a) attaching the open-ended frame (30, 130, 230) with the plurality of fiducial markers (48) to a patient using the maxillary holding device (50);

(b) acquiring a preoperative scan of the patient and the open-ended frame (30, 130, 230) with the plurality of fiducial markers (48);

(c) removing the maxillary holding device (50) from the patient;

(d) making a surgical plan, by the surgeon, from the preoperative scan;

(e) calculating the position of any point in or on the patient relative to the frame (30, 130, 230);

(f) attaching the reference emitter (90) to the frame (30, 130, 230);

(g) activating the tracking sensor (325) which then begins tracking the reference emitter (90) and the frame (30, 130, 230);

(h) calibrating the frame (30, 130, 230) and the reference emitter (90), while the patient is being prepared for surgery, so that the position of the frame (30, 130, 230) relative to the reference emitter (90) is determined;

(i) calculating the position of the frame (30, 130, 230) relative to the reference emitter (90);

(j) removing the frame (30, 130, 230) with the plurality of fiducial markers (48) from maxillary holding device (50);

(k) attaching the maxillary holding device (50) with the reference emitter (90) to the patient;

(l) calculating the position of any point in the intraoperative-imaged patient anatomy relative to the reference emitter (90);

(m) activating a surgical probe/instrument (320);

(n) tracking the reference emitter (90) and the surgical probe/instrument (320) simultaneously;

(o) calculating the position of the surgical probe/instrument (320) relative to the patient's anatomy; and

(p) using the image-guided surgical system (300) to guide surgery.

19. A method of calibrating an image-guided surgical system (300) that is used to perform image-guided surgery on a patient using a maxillary holding device (50), an open-ended frame (30, 130, 230), a plurality of fiducial markers (48), a reference emitter (90), a surgical probe/instrument (320) and the image-guided surgical system (300) having memory and a tracking sensor (325), the method comprising:

(a) attaching the open-ended frame (30, 130, 230) with the plurality of fiducial markers (48) to a patient using the maxillary holding device (50);

(b) acquiring a preoperative scan of the patient and the open-ended frame (30, 13, 230) with the plurality of fiducial markers (48);

(c) removing the maxillary holding device (50) from the patient;

(d) attaching the reference emitter (90) to either the open-ended frame (30, 130, 230) or the maxillary holding device (50);

(e) activating the tracking sensor (325) which then begins tracking the reference emitter (90);

(f) activating the surgical probe/instrument (320);

(g) tracking the reference emitter (90) and the surgical probe/instrument (320) simultaneously and continuously calculating the position of the surgical probe/instrument (320) relative to the reference emitter (90); and

(h) calibrating the image-guided surgical system (300) with respect to the frame (30, 130, 230) and the reference emitter (90) by touching the surgical probe/instrument (320) to each fiducial marker (48), so that the position of the frame (30, 130, 230) relative to the reference emitter (90) is determined and stored in the memory of the image-guided surgical system (300).